C++ Tutorial

Rob Jagnow

This tutorial will be best for students who have at least had some exposure to Java or another comparable programming language.

Overview

- Pointers
- Arrays and strings
- Parameter passing
- Class basics
- Constructors & destructors
- Class Hierarchy
- Virtual Functions
- Coding tips
- Advanced topics

Advanced topics: friends, protected, inline functions, const, static, virtual inheritance, pure virtual function (e.g. Intersect(ray, hit) = 0), class hierarchy.

Pointers

```
int *intPtr;
```

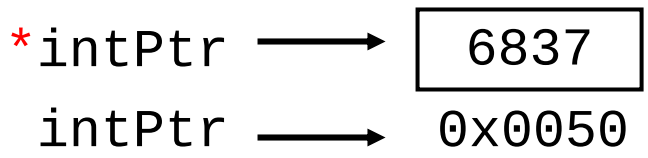
Create a pointer

```
intPtr = new int;
```

Allocate memory

```
*intPtr = 6837;
```

Set value at given address

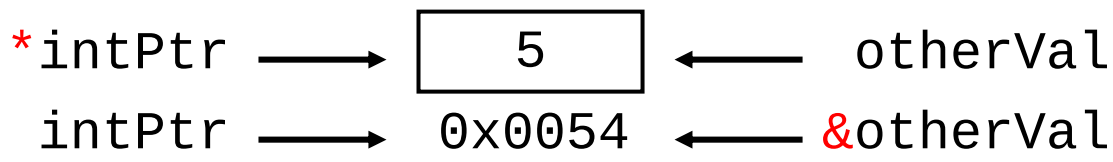



```
delete intPtr;
```

Deallocate memory

```
int otherVal = 5;
intPtr = &otherVal;
```

Change `intPtr` to point to a new location



Arrays

Stack allocation

```
int intArray[10];
intArray[0] = 6837;
```

Heap allocation

```
int *intArray;
intArray = new int[10];
intArray[0] = 6837;

...

delete[] intArray;
```

C++ arrays are zero-indexed.

Strings

A string in C++ is an array of characters

```
char myString[20];
strcpy(myString, "Hello World");
```

Strings are terminated with the `NULL` or `'\0'` character

```
myString[0] = 'H';
myString[1] = 'i';
myString[2] = '\0';

printf("%s", myString);
```

output: `Hi`

Parameter Passing

pass by value

```
int add(int a, int b) {
  return a+b;
}

int a, b, sum;
sum = add(a, b);
```

Make a local copy of a & b

pass by reference

```
int add(int *a, int *b) {
  return *a + *b;
}

int a, b, sum;
sum = add(&a, &b);
```

Pass pointers that reference a & b. Changes made to a or b will be reflected outside the add routine

Parameter Passing

pass by reference – alternate notation

```
int add(int &a, int &b) {
  return a+b;
}

int a, b, sum;
sum = add(a, b);
```

Class Basics

```
#ifndef _IMAGE_H_
#define _IMAGE_H_

#include <assert.h>
#include "vectors.h“

class Image {

public:
  ...

private:
  ...

};

#endif
```

Prevents multiple references

Include a library file

Include a local file

Variables and functions accessible from anywhere

Variables and functions accessible only from within this class

Note that “private:” is the default

Creating an instance

Stack allocation

```
Image myImage;
myImage.SetAllPixels(ClearColor);
```

Heap allocation

```
Image *imagePtr;
imagePtr = new Image();
imagePtr->SetAllPixels(ClearColor);

...

delete imagePtr;
```

Stack allocation: Constructor and destructor called automatically when the function is entered and exited.
Heap allocation: Constructor and destructor must be called explicitly.

Organizational Strategy

image.h

Header file: Class definition & function prototypes

```
void SetAllPixels(const Vec3f &color);
```

image.C

.C file: Full function definitions

```
void Image::SetAllPixels(const Vec3f &color) {
    for (int i = 0; i < width*height; i++)
      data[i] = color;
}
```

main.C

Main code: Function references

```
myImage.SetAllPixels(clearColor);
```

Constructors & Destructors

```
class Image {
public:
  Image(void) {
    width = height = 0;
    data = NULL;
  }

 ~Image(void) {
    if (data != NULL)
      delete[] data;
  }

  int width;
  int height;
  Vec3f *data;
};
```

Constructor:
Called whenever a new instance is created

Destructor:
Called whenever an instance is deleted

Constructors

Constructors can also take parameters

```
Image(int w, int h) {
  width = w;
  height = h;
  data = new Vec3f[w*h];
}
```

Using this constructor with stack or heap allocation:

```
Image myImage = Image(10, 10);
```

stack allocation

```
Image *imagePtr;
imagePtr = new Image(10, 10);
```

heap allocation

The Copy Constructor

```
Image(Image *img) {
  width = img->width;
  height = img->height;
  data = new Vec3f[width*height];
  for (int i=0; i<width*height; i++)
    data[i] = new data[i];
}
```

A default copy constructor is created automatically, but it is usually not what you want:

```
Image(Image *img) {
  width = img->width;
  height = img->height;
  data = img->data;
}
```

Warning: if you do not create a default (void parameter) or copy constructor explicitly, they are created for you.

Passing Classes as Parameters

If a class instance is passed by reference, the copy constructor will be used to make a copy.

```
bool IsImageGreen(Image img);
```

Computationally expensive

It's much faster to pass by reference:

```
bool IsImageGreen(Image *img);
```

or

```
bool IsImageGreen(Image &img);
```

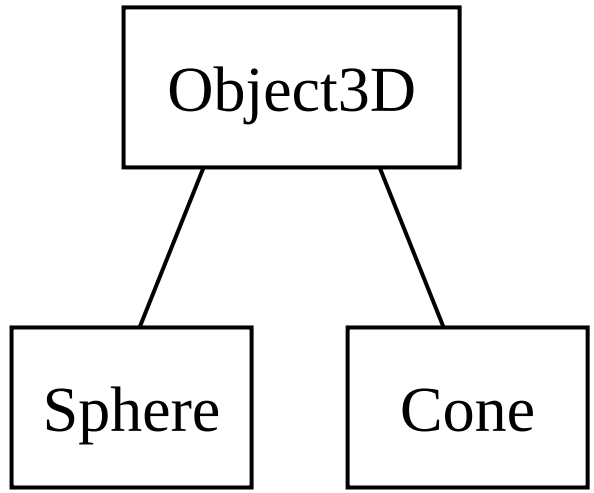
Class Hierarchy

Child classes inherit parent attributes

```
class Object3D {
  Vec3f color;
};

class Sphere : public Object3D {
  float radius;
};

class Cone : public Object3D {
  float base;
  float height;
};
```



Class Hierarchy

Child classes can *call* parent functions

```
Sphere::Sphere() : Object3D() {
  radius = 1.0;
}
```

Call the parent constructor

Child classes can *override* parent functions

```
class Object3D {
  virtual void setDefaults(void) {
    color = RED; }
};

class Sphere : public Object3D {
  void setDefaults(void) {
    color = BLUE;
    radius = 1.0 }
};
```

Virtual Functions

A superclass pointer can reference a subclass object

```
Sphere *mySphere = new Sphere();
Object3D *myObject = mySphere;
```

If a superclass has virtual functions, the correct subclass version will automatically be selected

Superclass

```
class Object3D {
  virtual void intersect(Vec3f *ray, Vec3f *hit);
};
```

Subclass

```
class Sphere : public Object3D {
  virtual void intersect(Vec3f *ray, Vec3f *hit);
};
```

```
myObject->intersect(ray, hit);
```

Actually calls `Sphere::intersect`

The `main` function

This is where your code begins execution

```
int main(int argc, char** argv);
```

Number of arguments

Array of strings

`argv[0]` is the program name

`argv[1]` through `argv[argc-1]` are command-line input

Coding tips

Use the `#define` compiler directive for constants

```
#define PI 3.14159265
#define sinf sin
```

Use the `printf` or `cout` functions for output and debugging

```
printf("value: %d, %f\n", myInt, myFloat);
cout << "value:" << myInt << ", " << myFloat << endl;
```

Use the `assert` function to test “always true” conditions

```
assert(denominator != 0);
quotient = numerator/denominator;
```

“Segmentation fault (core dumped)”

Typical causes:

```
int intArray[10];
intArray[10] = 6837;
```

Access outside of array bounds

```
Image *img;
img->SetAllPixels(ClearColor);
```

Attempt to access a NULL or previously deleted pointer

These errors are often very difficult to catch and can cause erratic, unpredictable behavior.

Advanced topics

Lots of advanced topics, but few will be required for this course

- `friend` or `protected` class members
- inline functions
- `const` or `static` functions and variables
- *pure* virtual functions

```
virtual void Intersect(Ray &r, Hit &h) = 0;
```

- compiler directives
- operator overloading

```
Vec3f& operator+(Vec3f &a, Vec3f &b);
```